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OPTICAL PHASED ARRAY FILTER MODULE WITH PASSIVELY COMPENSATED TEMPERATURE DEPENDENCE

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Abstract: We present WDM filter-modules, realised in silica-on-silicon, which are stabilized against thermal drifts using a modified input coupling section where the thermal expansion of a compensating rod shifts the input fibre thus retuning the filter.

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Introduction

In the early stages of WDM system development channel spacing was large enough that the thermal drifting of the peak wavelength was tolerated for both lasers and filters. With decreasing channel spacing it is a crucial requirement to stabilize the lasers temperature for an exact frequency tuning. For filters however it is preferred to stabilize them passively against thermal drifts because the system's control overhead may be reduced. Several different solutions have been proposed to achieve this. Dielectric filters deposited with special material technologies exhibit a fairly low temperature coefficient which seems to be sufficient for some applications. Fibre Bragg gratings are thermally stabilized using housings with zero or negative thermal expansion coefficients /1/. Athermal waveguides have been designed both in InP and silica-on-silicon /2,3,4/. However, these require a more complicated fabrication technology or exhibit additional insertion losses. We present here an approach where the temperature dependence of optical phased array filters is compensated not on the chip but with a modified input coupling section.

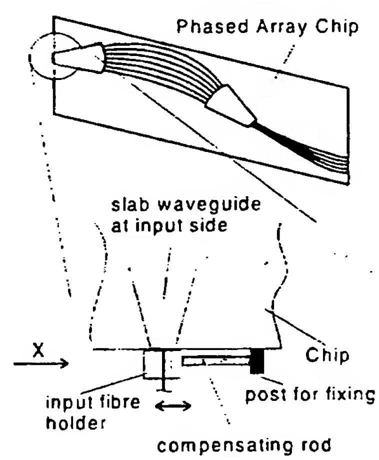
Design

Previously we have shown that the centre wavelength λ_c of an optical phased array may be adapted to a specified wavelength by coupling the input signal directly into the first slab waveguide in front of the phase shifter /5/. Within a certain lateral range the input fibre can be moved to select the appropriate centre wavelength. When the phased array is designed symmetrically, the tuning rate $d\lambda/dx$ is given by the linear dispersion D of the phased array i.e. the spectral channel separation divided by output waveguides spatial separation at the end of the second slab waveguide. Usually we tune the filter modules to align them to the standard ITU frequency grid thus compensating for chip fabrication tolerances. The aligned input fibre is glued directly to the chip to achieve a reliable fibre chip coupling.

To compensate the temperature drift of the phased array chip, this input coupling scheme has been modified. A detailed view of the new coupling principle is given in figure 1.

The input coupling device consists of three parts: namely one part holding the input fibre as before (i), an additional post to fix the whole coupling device to the chip (ii) and a compensating rod between them (iii). The compensating rod is made of a material with a high thermal expansion coefficient α_c. It changes its length with the ambient temperature T and shifts the input fibre along the endface of the slab waveguide to compensate the thermal drift $\Theta = d\lambda/dT$ of the filter chip. The appropriate length L of the compensating rod can be derived as follows:

Fig. 1: Temperature compensating input device.



The centre wavelength of the filter chip changes as

$$\Delta\lambda_c = \Theta \cdot \Delta T$$

which has to be compensated by shifting the input fibre the distance

$$\Delta x = 1/(\,d\lambda/dx\,) \cdot \Delta\lambda_c = \Theta / D \cdot \Delta T$$

On the other hand the thermal expansion of the compensating rod shift the input fibre by:

$$\Delta x = \alpha \cdot L \cdot \Delta T$$

with α being the difference of the thermal expansion coefficients of the filter chip and the input coupling device. Hence we get

$$\alpha \cdot L = \Theta / D.$$

Using e.g. aluminium for the compensating rod we need a length of 2.8 mm for our 400 GHz filter chip realised as phased array in the silica on silicon material system with a thermal drift of θ = 10 pm/K and a linear dispersion of D = 3.2 nm/20 µm.. For a 200 GHz chip with half its linear dispersion, the compensating rod is with 5.6 mm twice as long.

It should be pointed out that this kind of temperature drift compensation is independent of the chip's material and can be applied with different types of spectrometers such as phased array filters and flat field spectrometers /6/.

Measurements

We have tested our modules containing filter chips designed for both 400 and 200 GHz channel spacing. Details of their design and on its fabrication process are given in /5,7/. All the measurements shown in the following figures were performed using a tuneable laser source and an optical power meter. The filter transmission at room temperature of a 200 GHz module with 16 channels is shown in figure 2. It exhibits an insertion loss of <5 dB, measured from connector to connector (E2000, high return loss), and a crosstalk level of >30 dB. The shift between the transmission curves for TE and TM polarisation is below 5 GHz and is not resolved in figure 2.

In figure 3 we show the shift of several channel's peak transmission with temperature for a 400 GHz module (top) and a 200 GHz module (bottom). The temperature is varied from -35 to +80°C. The 400 GHz module seems to be slightly overcompensated showing a remaining temperature dependence of -0.6 pm/K as derived from a linear fit. For the 200 GHz Module, the peak transmission of the module does not changes at all with the temperature.

Even with the module's peak transmission wavelength stabilized against environmental temperature drifts, the insertion loss at a specified wavelength shows a weak temperature dependence. In the range from -35 to +70°C the change in insertion loss remains within 1 dB. However, this loss is also seen in modules with a conventional fixed input coupling.

Conclusions

We have realised athermal DWDM filter modules based on phased array chips realised in the silicon on silica material system. The temperature dependence inherent to the chip of $d\lambda/dT = 10$ pm/K is compensated using a movable input fibre. This fibre is moved by the thermal expansion of a properly designed compensating rod. In this way the centre wavelength of the filter is tuned back to the desired value, and becomes nearly independent of the ambient temperature. This method may be applied to spectrographs and phased array filters realised in any material.

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Fig. 2: Filter transmission of a phased array module with 16 channels separated 200 GHz.

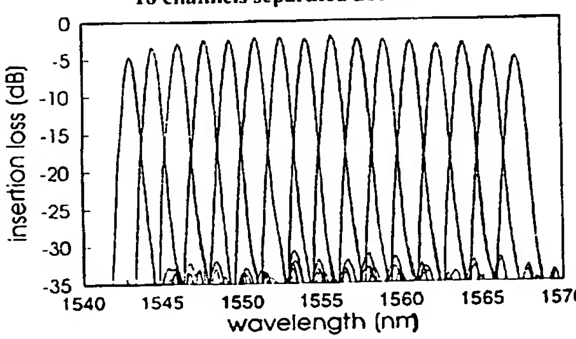
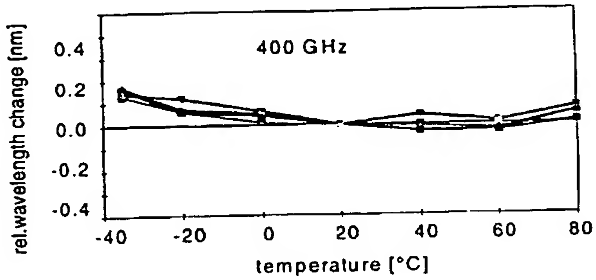
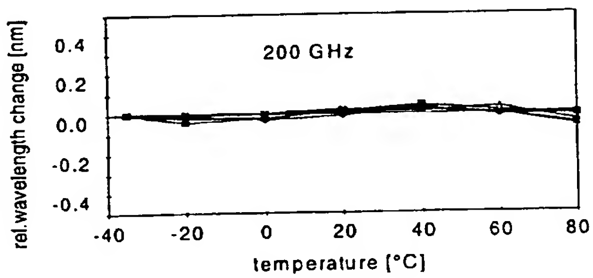


Fig. 3: Temperature dependence of peak transmission for 400 GHz (upper) and 200 GHz (lower) modules. Several points at each temperature are measured at different channels of each module.





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